MONOLITHIC SELF-SUPPORTIVE BI-DIRECTIONAL BENDING PNEUMATIC BELLOWS CATHETER

The minimally invasive surgery has proven to be advantageous over conventional open surgery in terms of reduction in recovery time, patient trauma, and overall cost of treatment. To perform a minimally invasive procedure, preliminary insertion of a flexible tube or catheter is crucial without sacrificing its ability to maneuver. Nevertheless, despite the vast amount of research reported on catheters, the ability to implement active catheters in the minimally invasive application is still limited. To date, active catheters are made of rigid structures constricted to the use of wires or on-board power supplies for actuation, which increases the risk of damaging the internal organs and tissues. To address this issue, an active catheter made of soft, flexible and biocompatible structure, driven via nonelectric stimulus is of utmost importance. This study presents the development of a novel monolithic self-supportive bi-directional bending pneumatic bellows catheter using a sacrificial molding technique. As a proof of concept, for understanding the effects of structural parameters on the bending performance of bellows-structured actuator, a single channel circular bellows pneumatic actuator was designed. Finite element analysis was performed to analyze the unidirectional bending performance, while the most optimal model was fabricated for experimental validation. Moreover, to attain biocompatibility and bidirectional bending, the novel monolithic polydimethylsiloxane (PDMS)-based dual-channel square bellows pneumatic actuator was proposed. The actuator was designed with an overall cross-sectional area of 5 × 5 mm², while the input sequence and the number of bellows were characterized to identify their effects on the bending performance. A novel sacrificial molding technique was adopted for developing the monolithic-structured actuator, which enabled simple fabrication for complex designs. The experimental validation revealed that the actuator model with size of 5 × 5 × 68.4 mm³ i.e. having the highest number of bellows attained optimal bi-directional bending with maximum angles of -65° and 75°, and force of 0.166 and 0.221 N under left and right channel actuation, respectively, at 100 kPa pressure. The bending performance characterization and thermal insusceptibility achieved by the developed pneumatic catheter presents a promising implementation of flexibility and thermal stability for various biomedical applications, such as dialysis and cardiac catheterization.